Computation of Signal Gain and Noise Gain of a SAR Processor

Ulrich Balss, Helko Breit, Andreas Niedermeier

German Aerospace Center (DLR)
Remote Sensing Technology Institute (IMF)

Outline

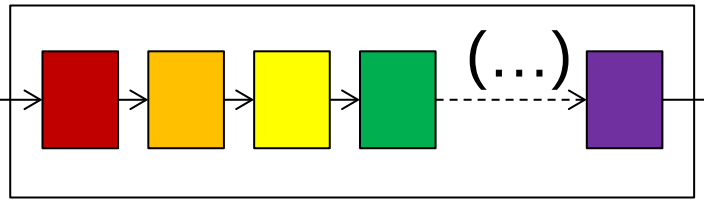
- Introduction
- Energy Normalization vs. Power Normalization
- Range (Pre-)Compression and Chirp Energy
- Azimuth Compression and Aperture Length
- Signal Gain vs. Noise Gain
- White and Colored Noise
- Tracking Signal and Noise Power through the Focusing Chain
- Conclusions

Signal Gain of a SAR Processor
(Simplified Model)

$$gain := \frac{\frac{1}{N'M'}\sum_{i,j} {s_{img}}^2(i,j)}{\frac{1}{NM}\sum_{i,j} {s_{raw}}^2(i,j)}$$

Signal and Noise Gain
(More Detailed Sight)

$S_{raw}(i,j)+n_{rec}(i,j)$



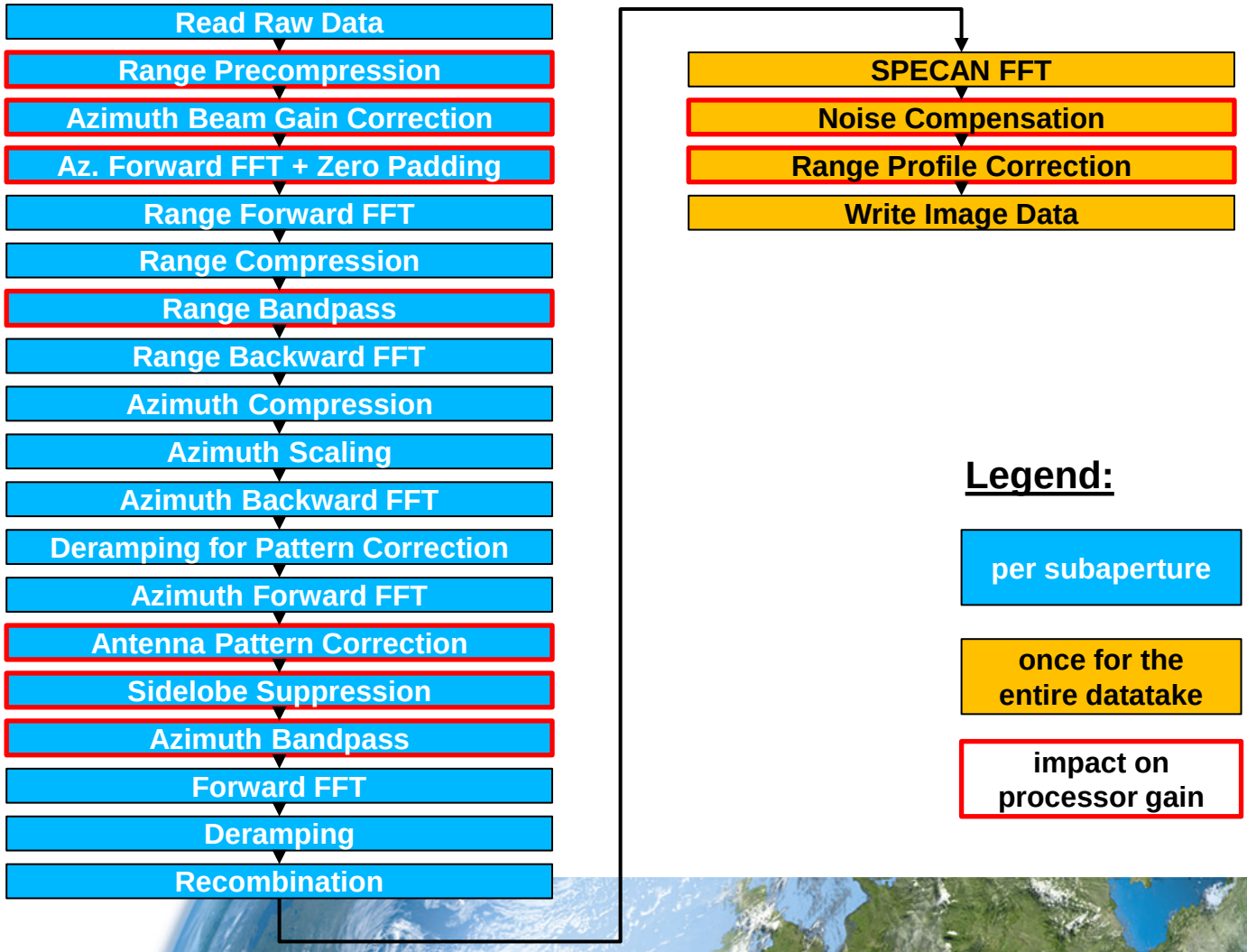
$S_{img}(i,j)+n_{img}(i,j)$

Input consists of SAR raw data and receiver noise

Several different processing steps

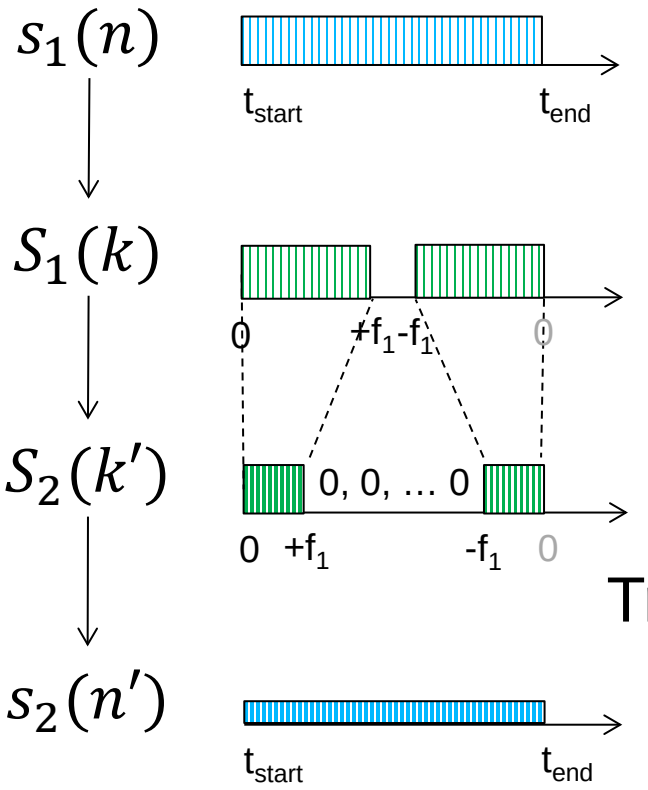
output consists of SAR data and image noise

Extended Chirp Scaling:
Processing Chain for Sliding Spotlight Data



Energy versus Power Normalization

Changing the sampling rate of a signal:



Transform to spectral domain

Spectral zero padding
(energy normalized)

Transform back to time domain

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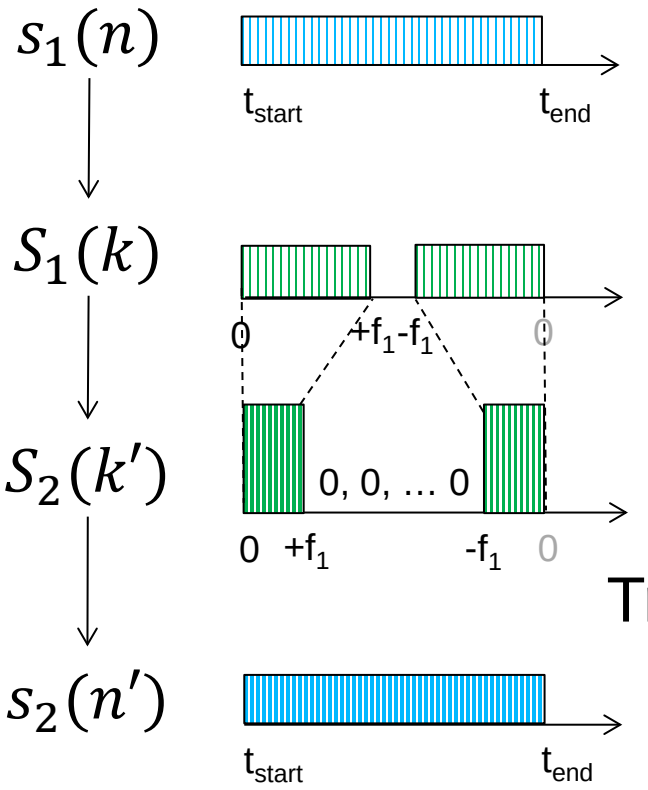

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Transform back to time domain

Range Precompression

$$s_{rc}(t,\tau) = s_{raw}(t,\tau) * r(-\tau)$$

Convolution with time reversed chirp replica in time domain

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Multiplication by conjugate complete spectrum of chirp replica

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Ditto. with normalization:
Chirp energy occurs twice
(in replica ***and in the signal***)

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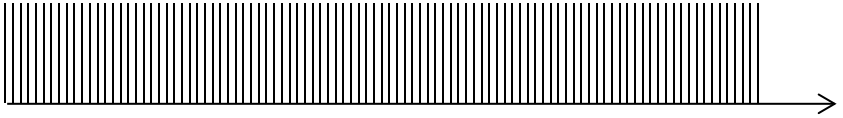
A threshold avoids division by low values (or even zero)!

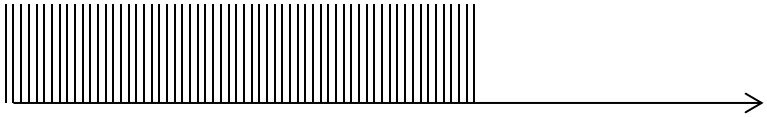
Azimuth Compression

short aperture (e.g. ScanSAR):

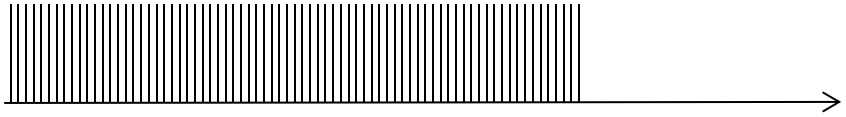
long aperture (e.g. Staring Spotlight):



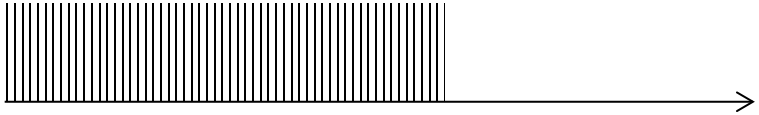
short aperture (e.g. near range beam):



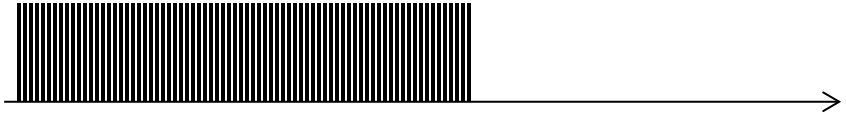
long aperture (e.g. far range beam):



low PRF:



high PRF:



Received signal energy depends on:

- backscatter coefficient **(wanted)**
- number of echo pulses in aperture **(unwanted)**

Azimuth Compression

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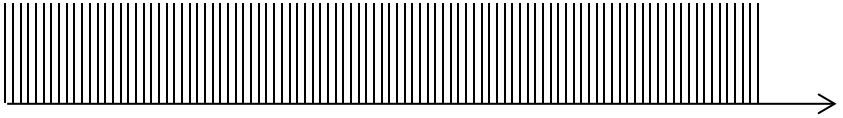

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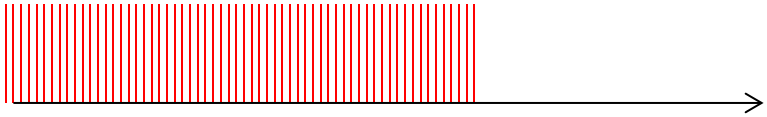

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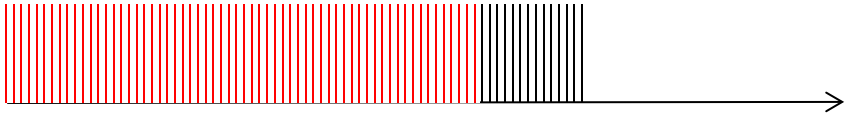
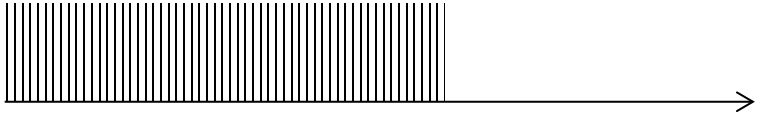


low PRF:



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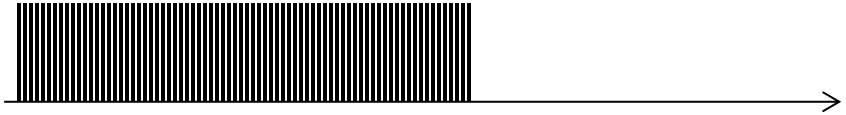

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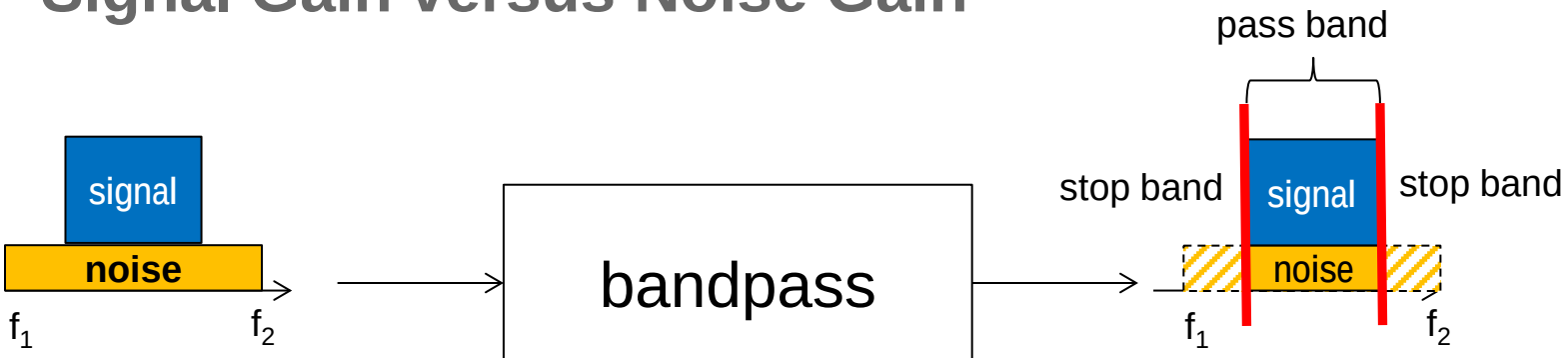
Signal Gain versus Noise Gain



Input:
narrow-band signal +
wideband noise

Output:
narrow band signal +
narrow-band noise

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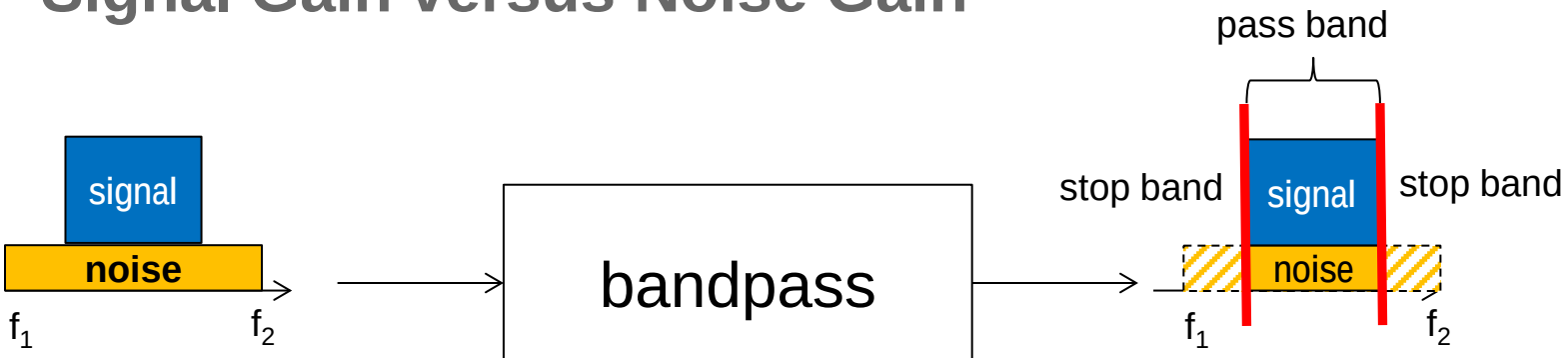

Input:
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Output:
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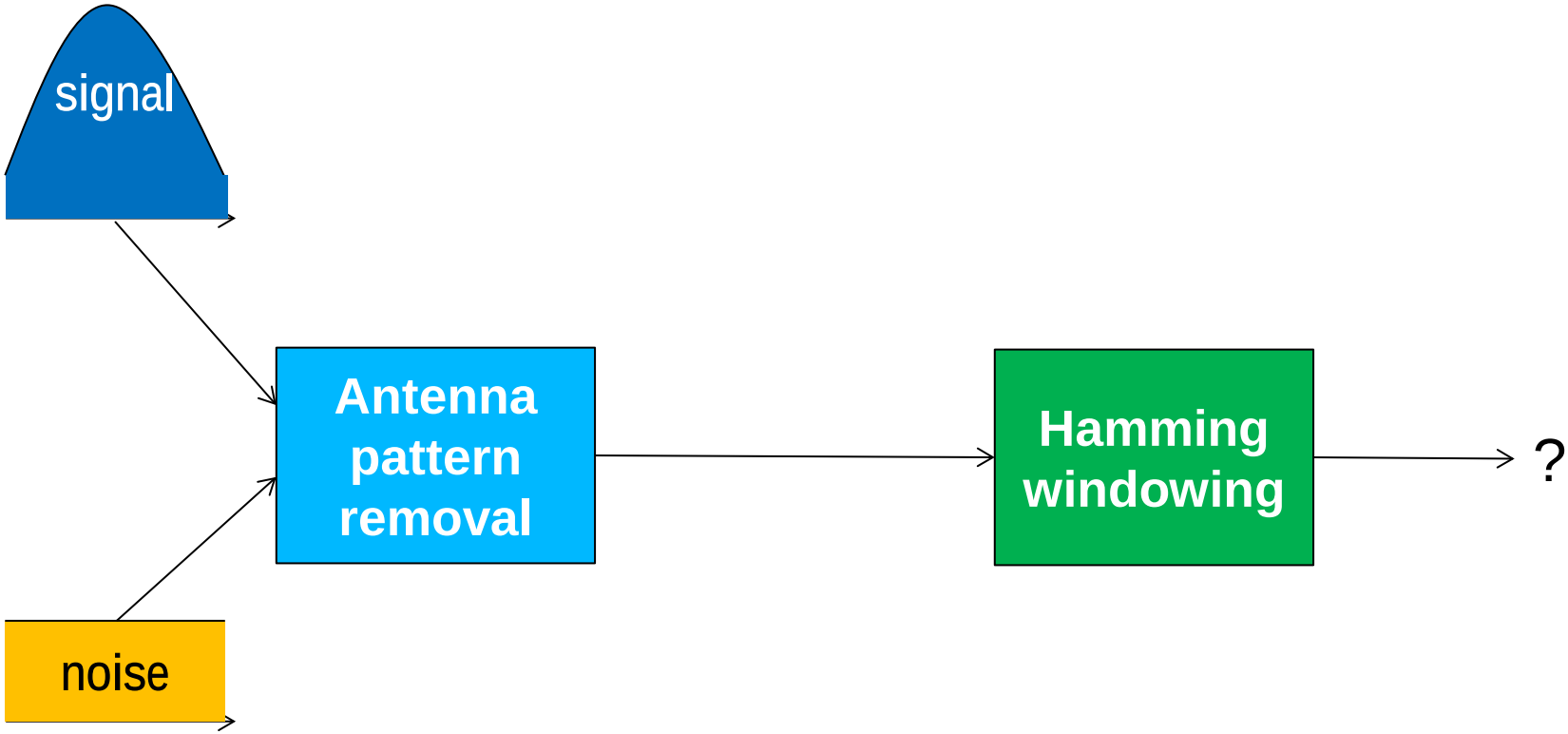
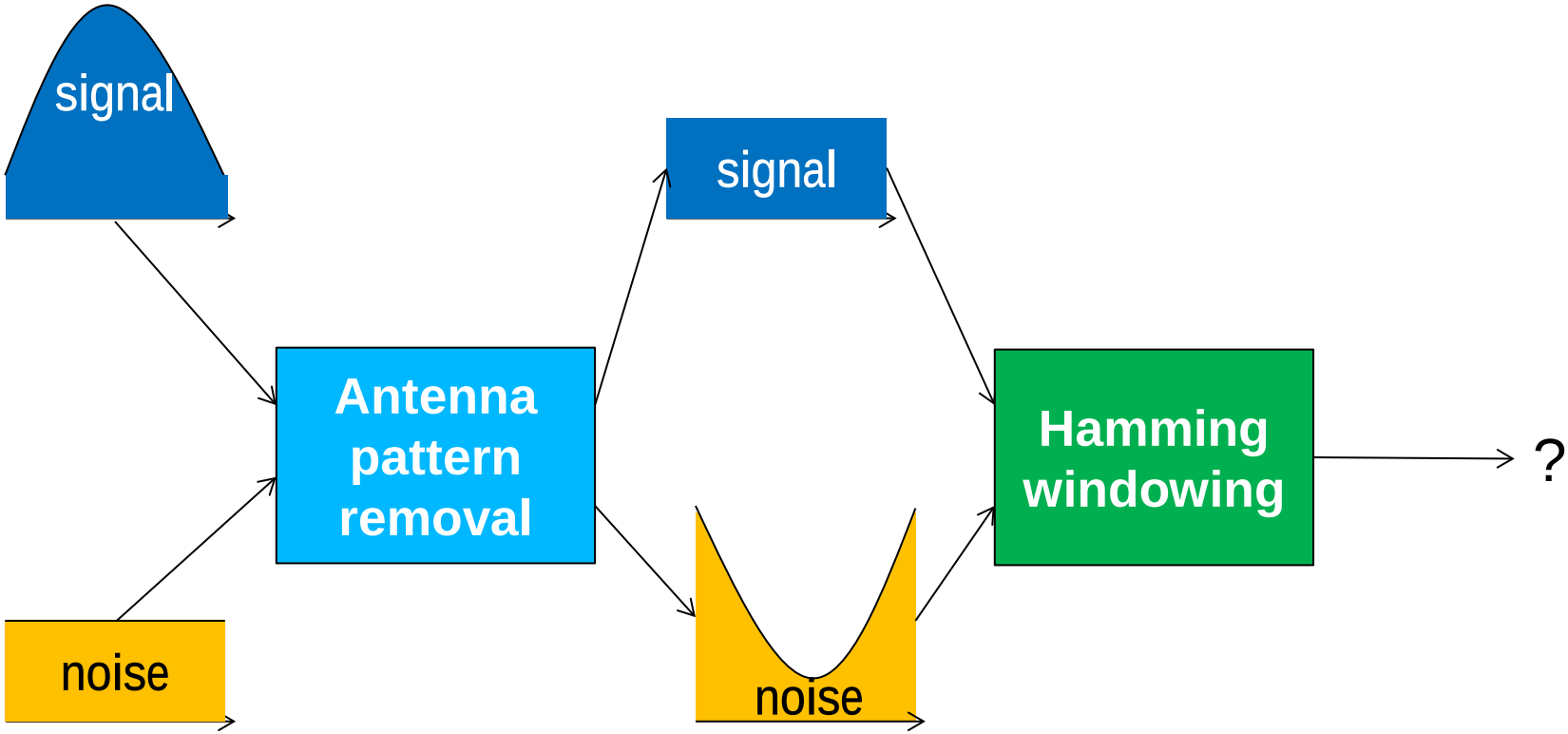
If bandwidth of signal and noise differs:
Different portions of signal and of noise energy are removed.
Consequently, signal and noise gain of the filter are different.

White and Colored Noise



White and Colored Noise



$$noise\ gain_{APR} = \frac{\int (N(f) \cdot A_{APR}(f))^2 df}{\int N(f)^2 df}$$

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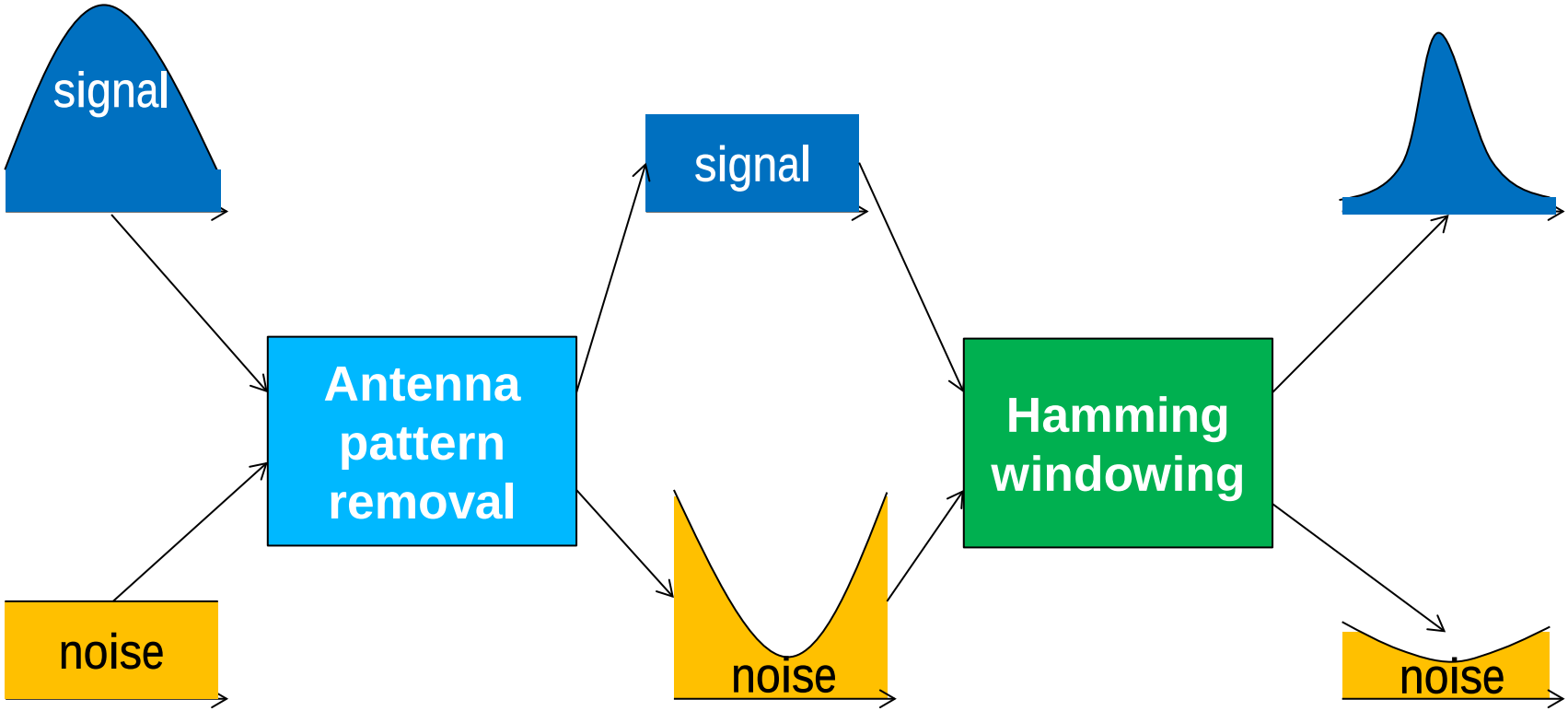
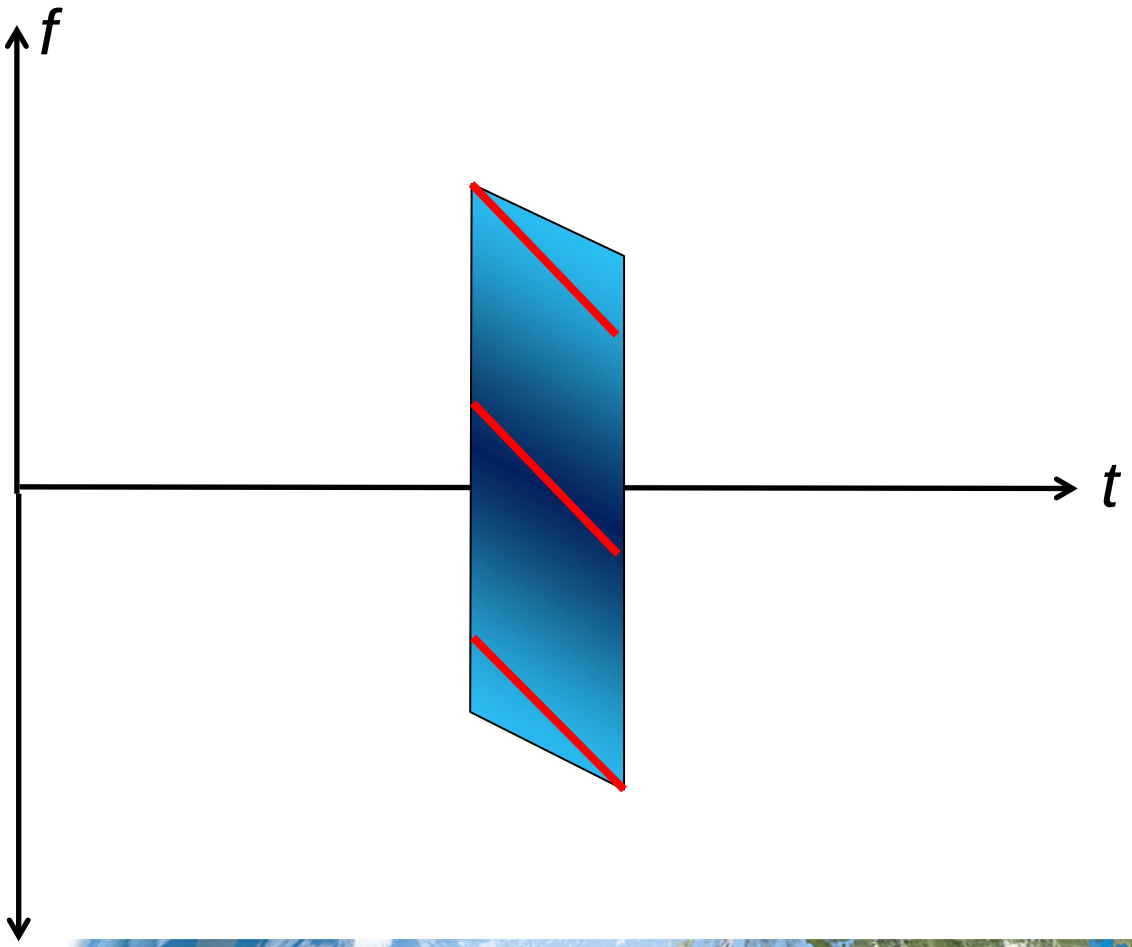
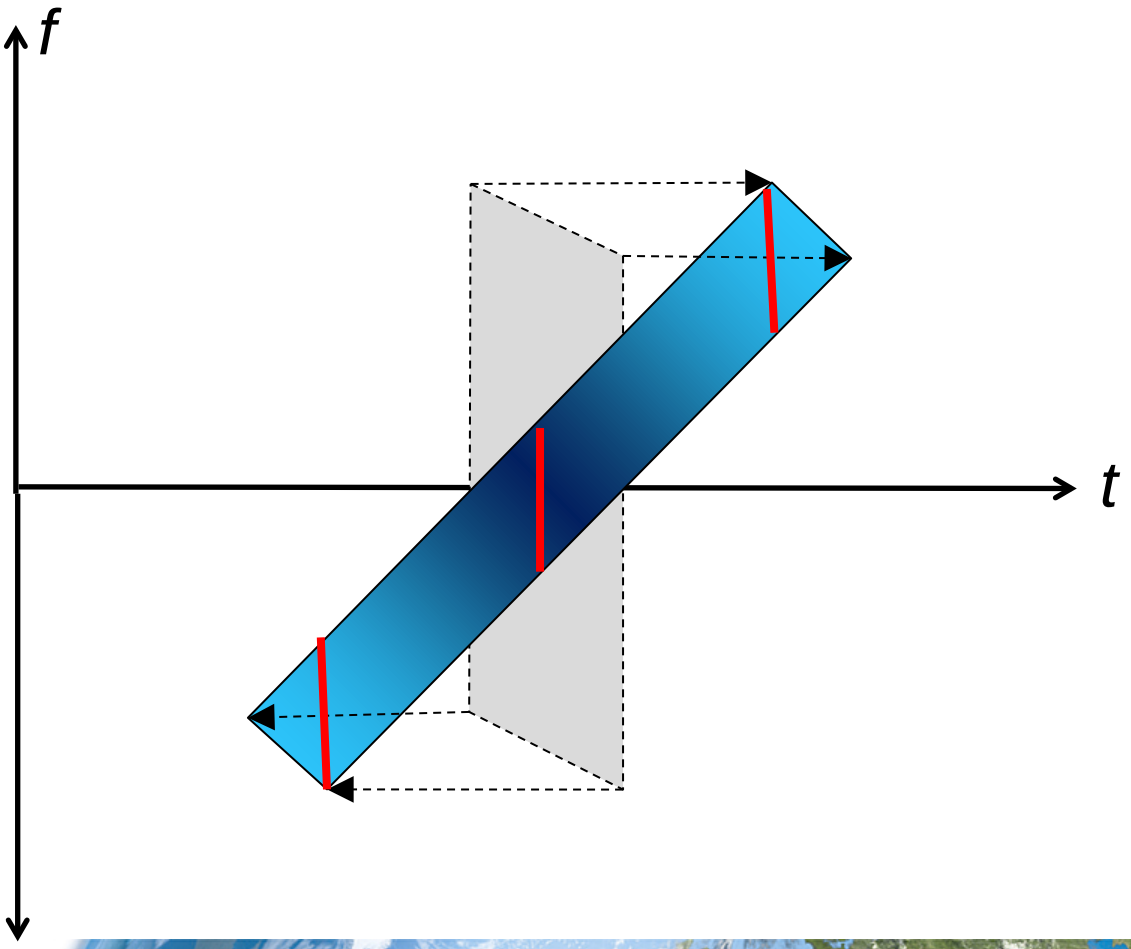


$$noise\ gain_{HW} = \frac{\int (N(f) \cdot \boldsymbol{A_{APR}(f)} \cdot A_{HW}(f))^2 df}{\int (N(f) \cdot \boldsymbol{A_{APR}(f)})^2 df}$$

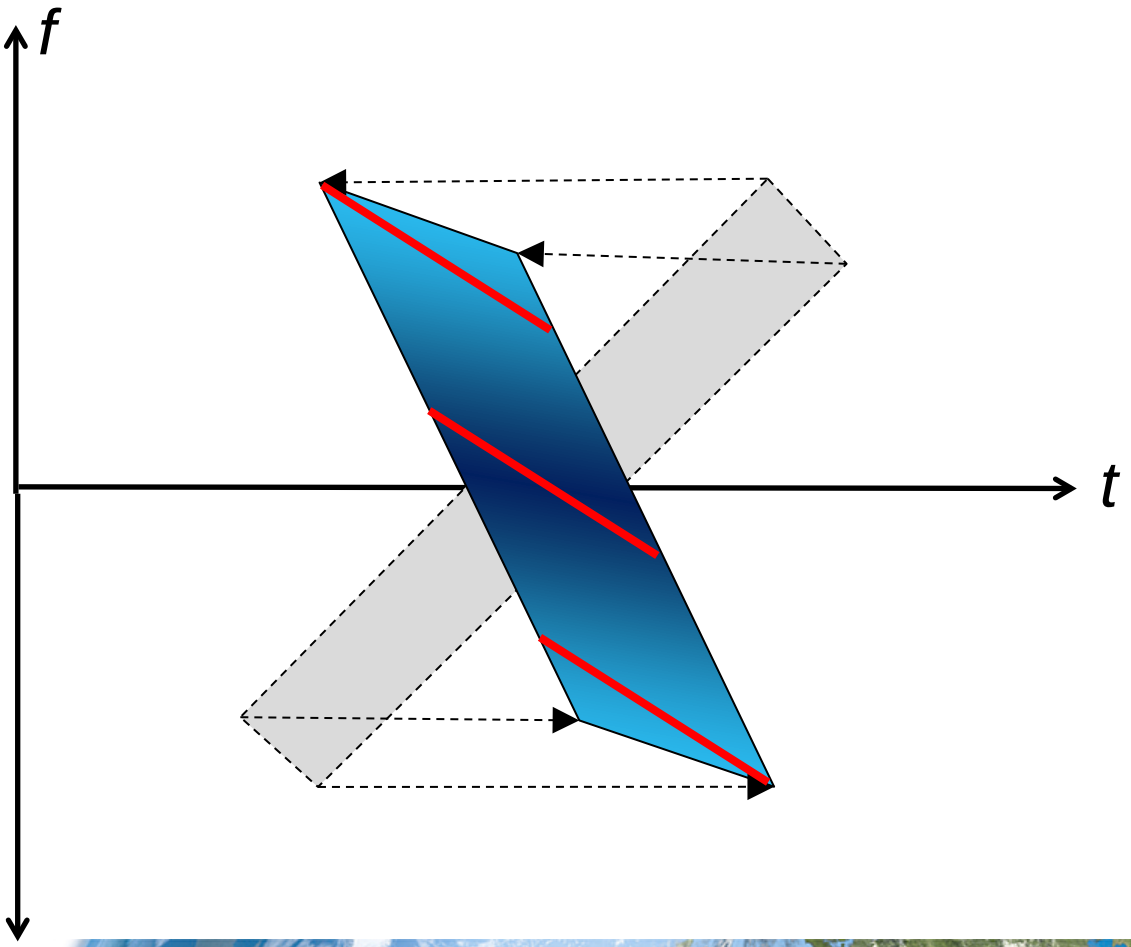
Tracking the Signal through the SAR Processor (Range Compressed Data)



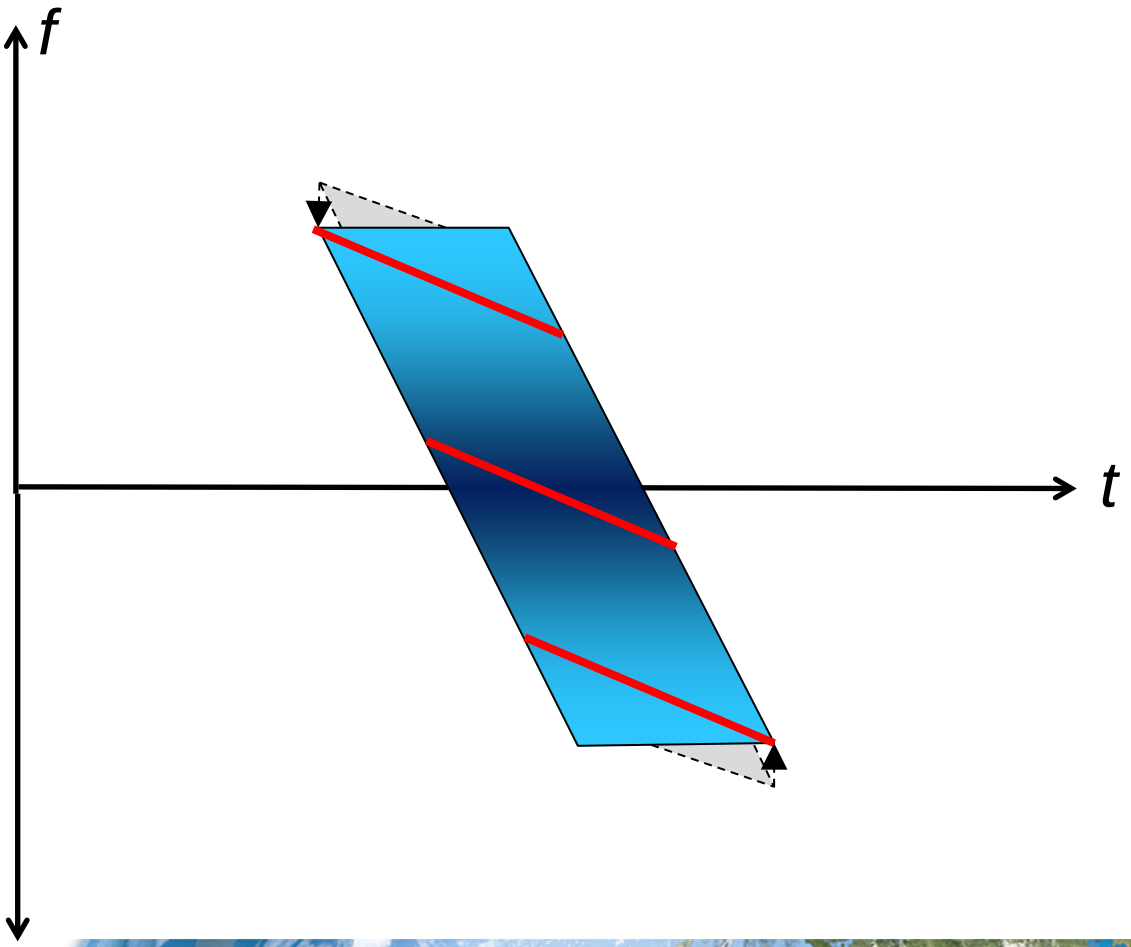
Tracking the Signal through the SAR Processor (Azimuth Compression)



Tracking the Signal through the SAR Processor (Azimuth Scaling)



Tracking the Signal through the SAR Processor (Deramping for Antenna Pattern Removal)



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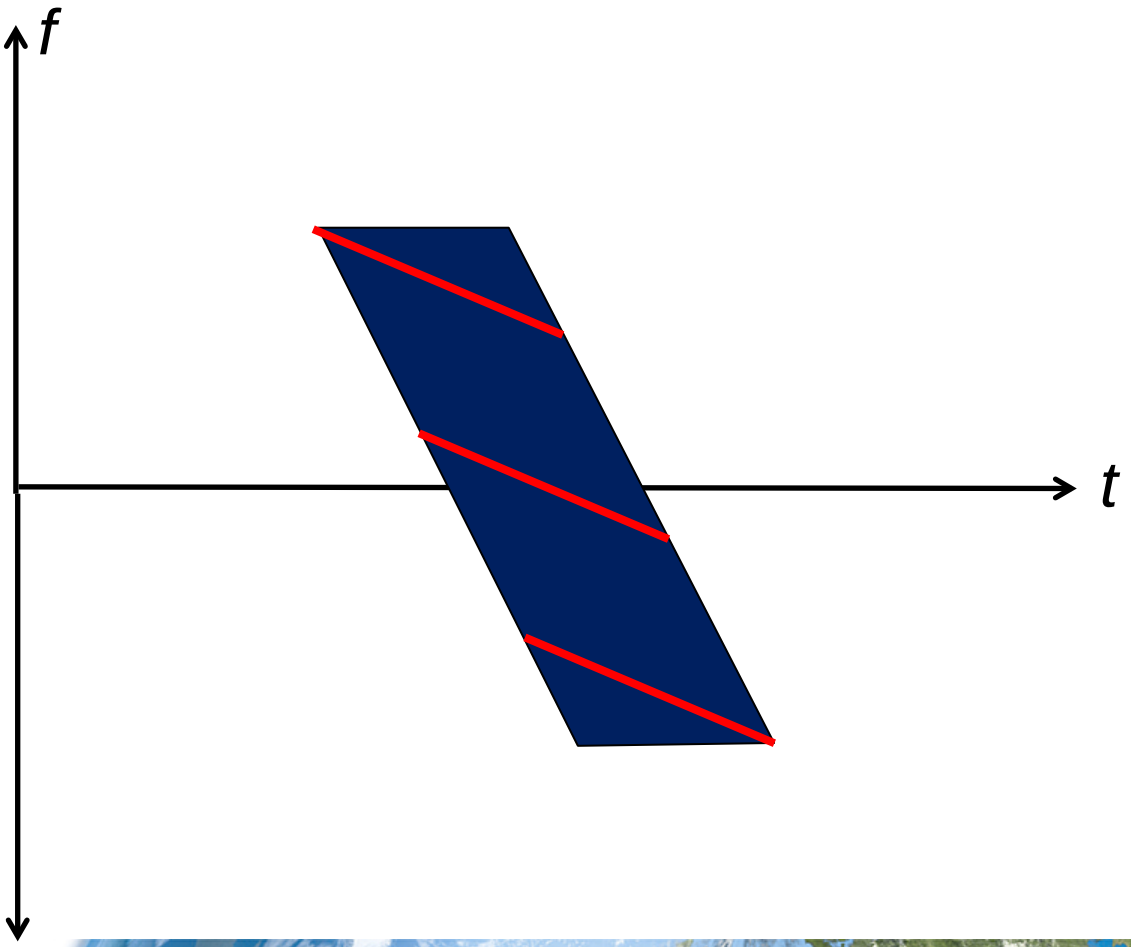
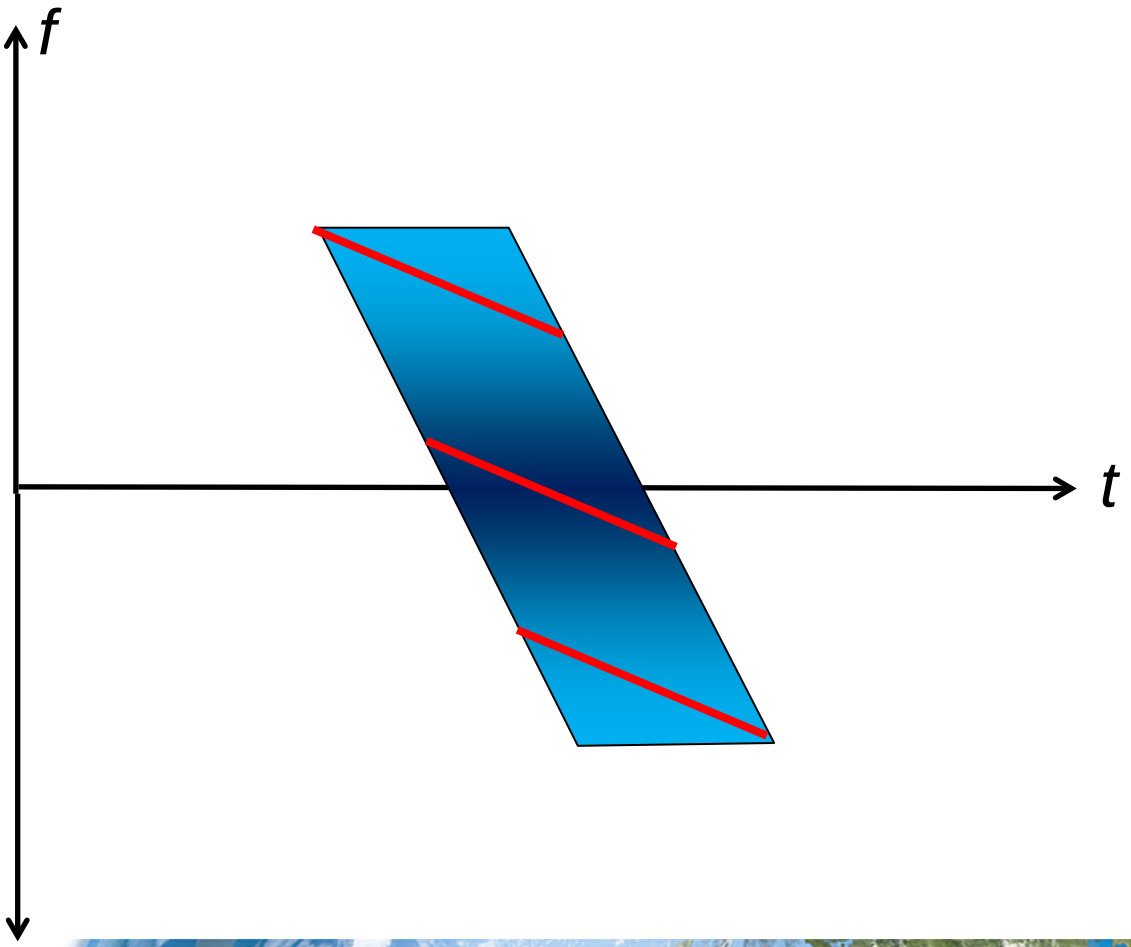
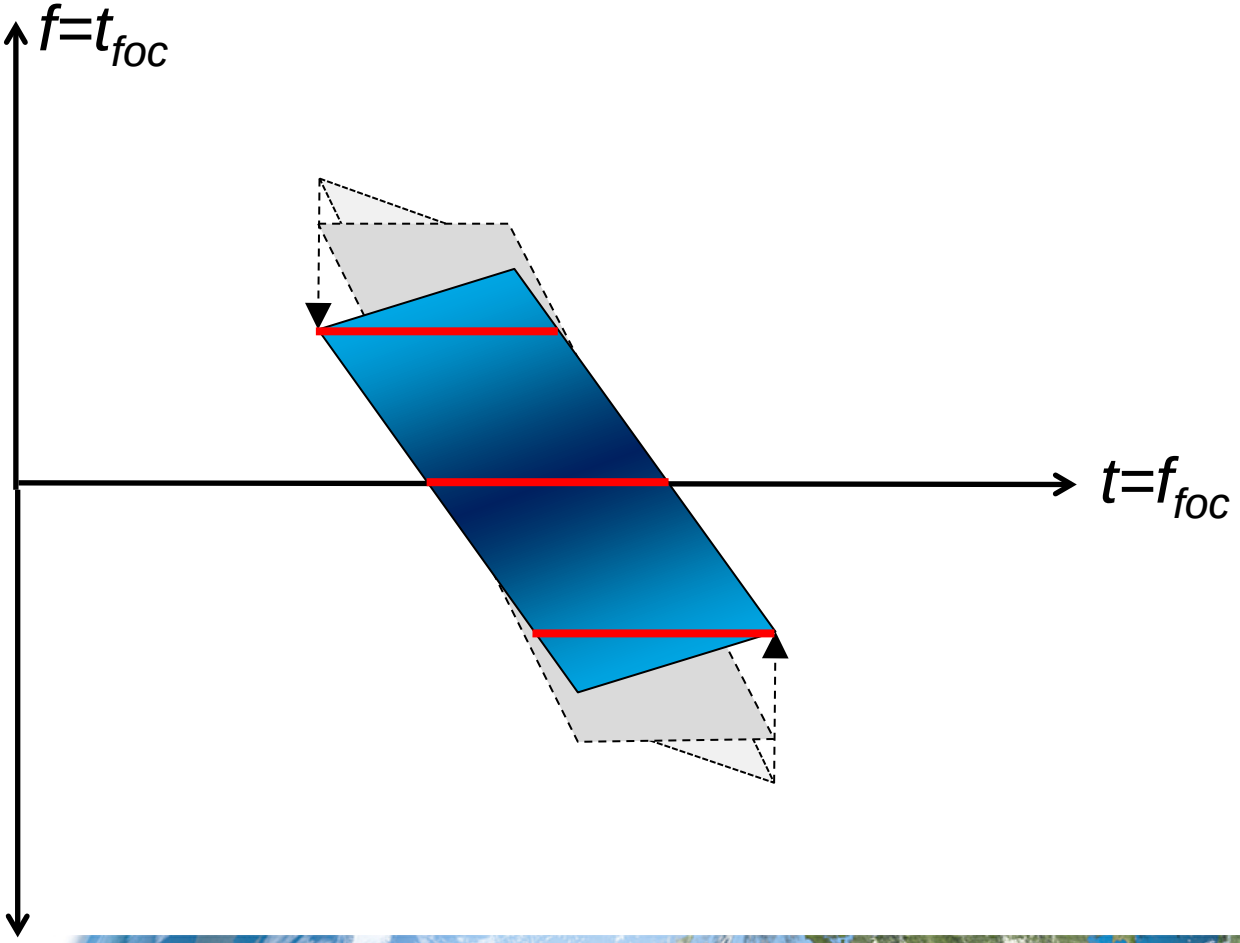


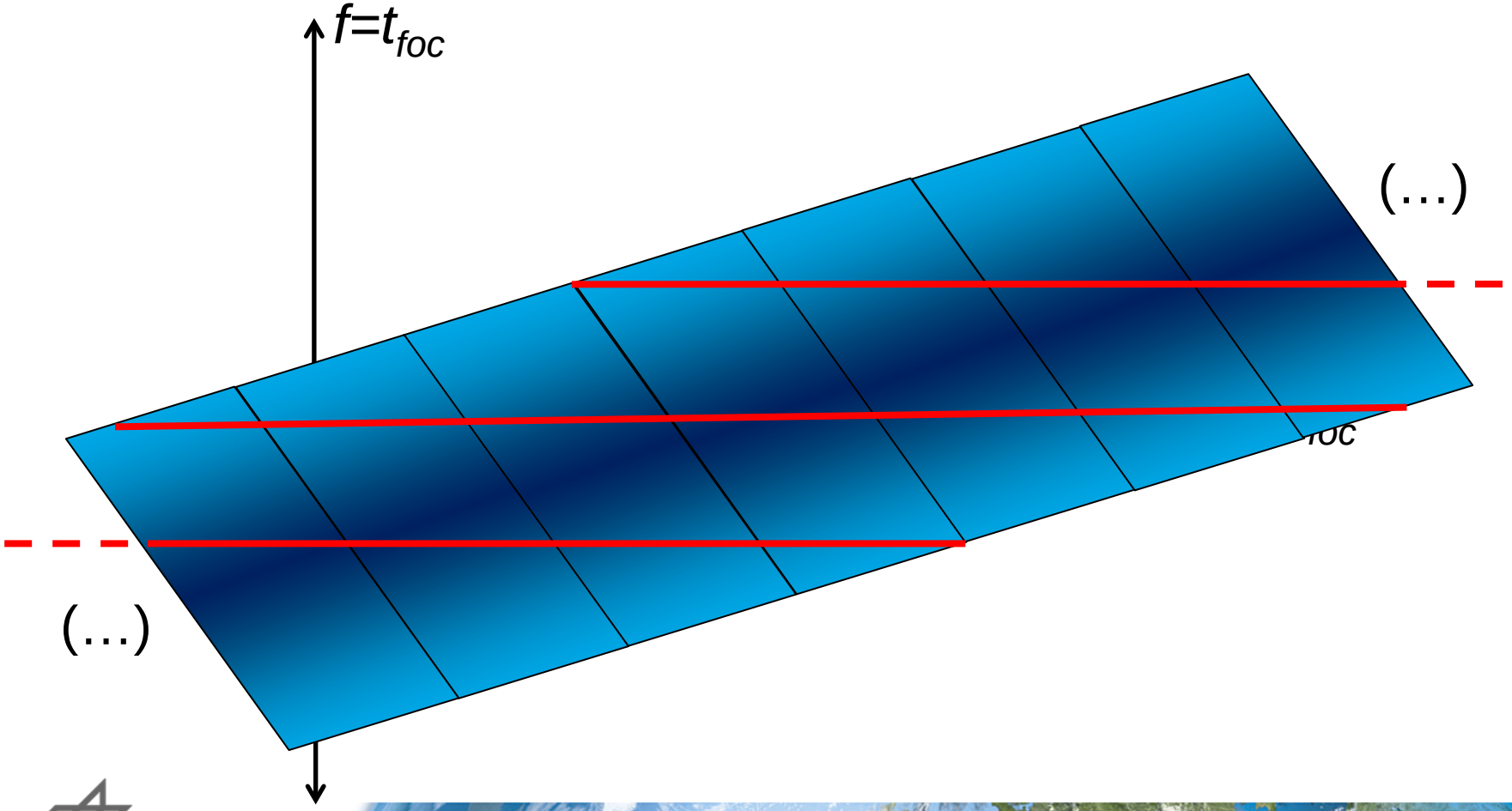
Tracking the Signal through the SAR Processor (Multiply by Hamming Window)



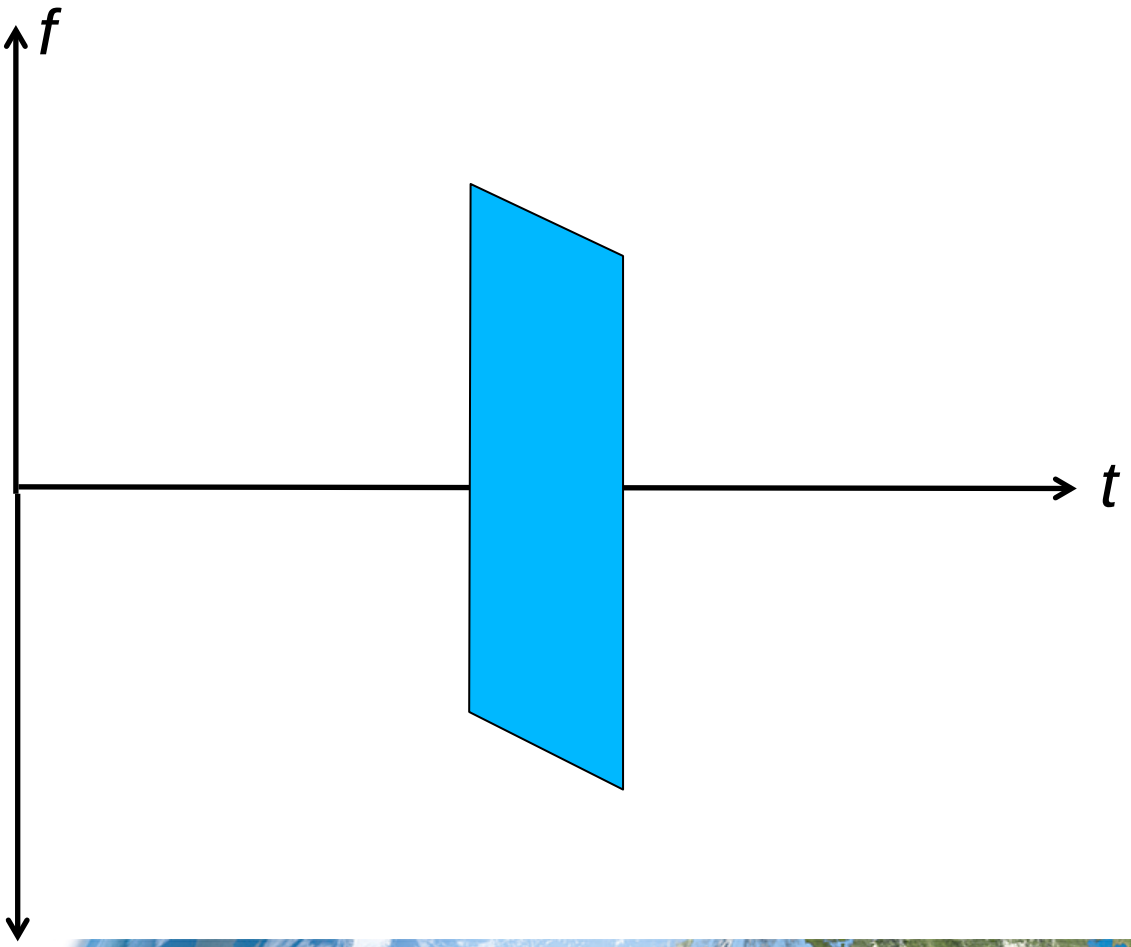
Tracking the Signal through the SAR Processor (Residual Deramping)



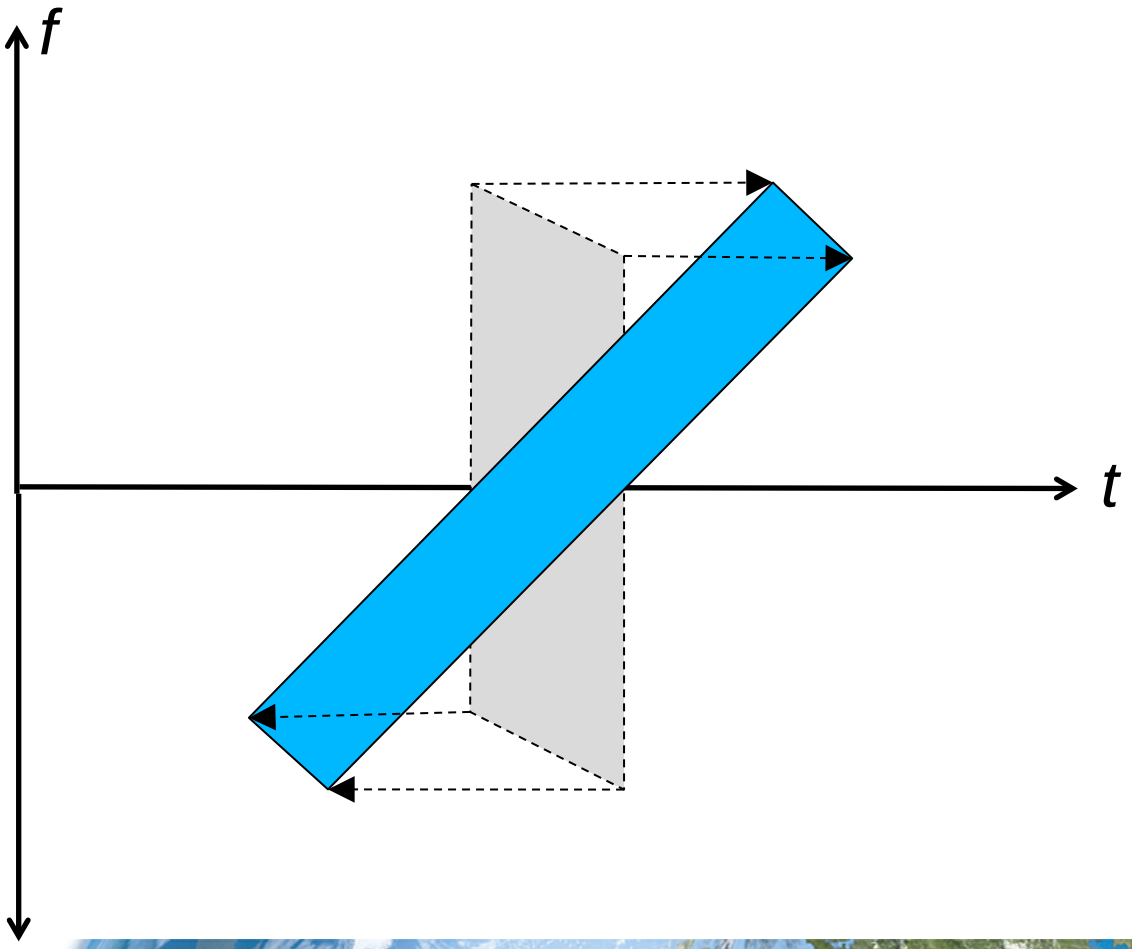
Tracking the Signal through the SAR Processor (Recombination)



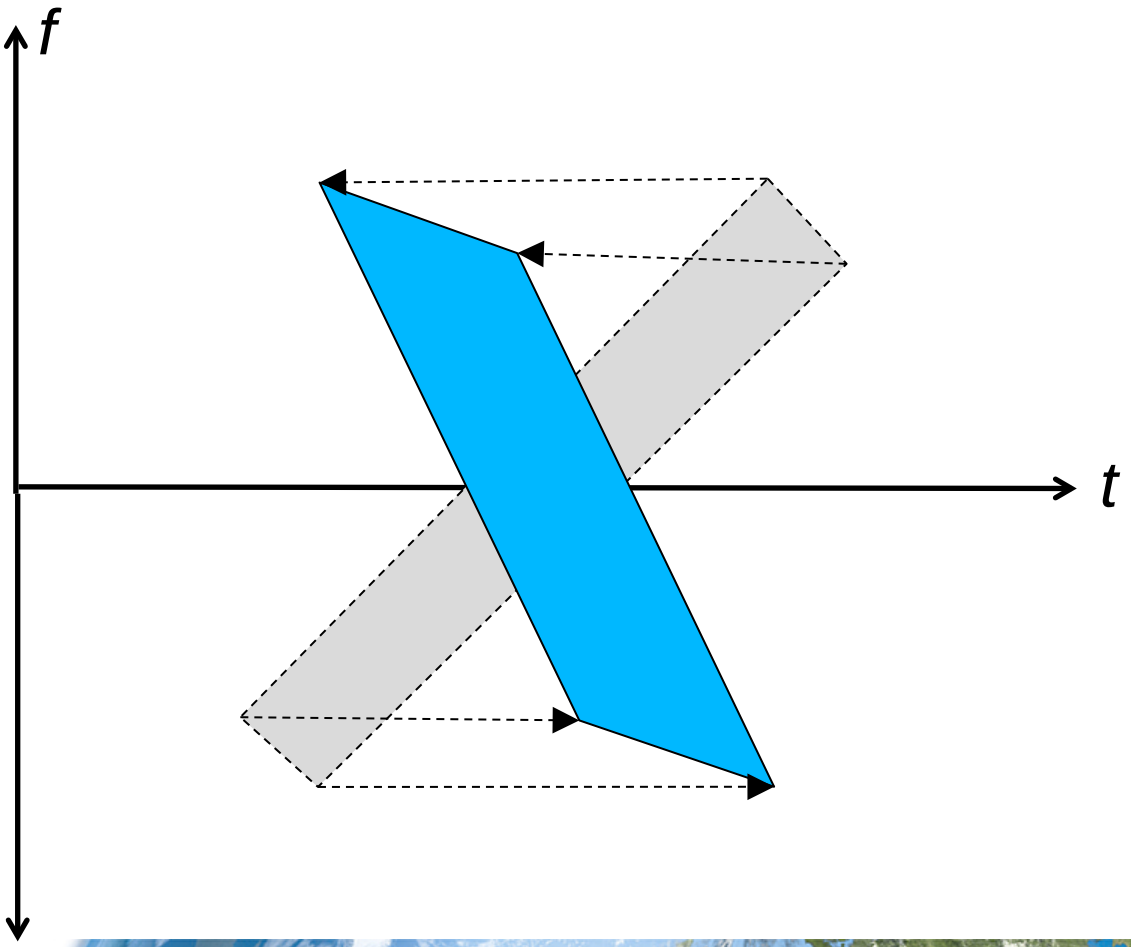
Tracking the Noise through the SAR Processor (Range Compressed Data)



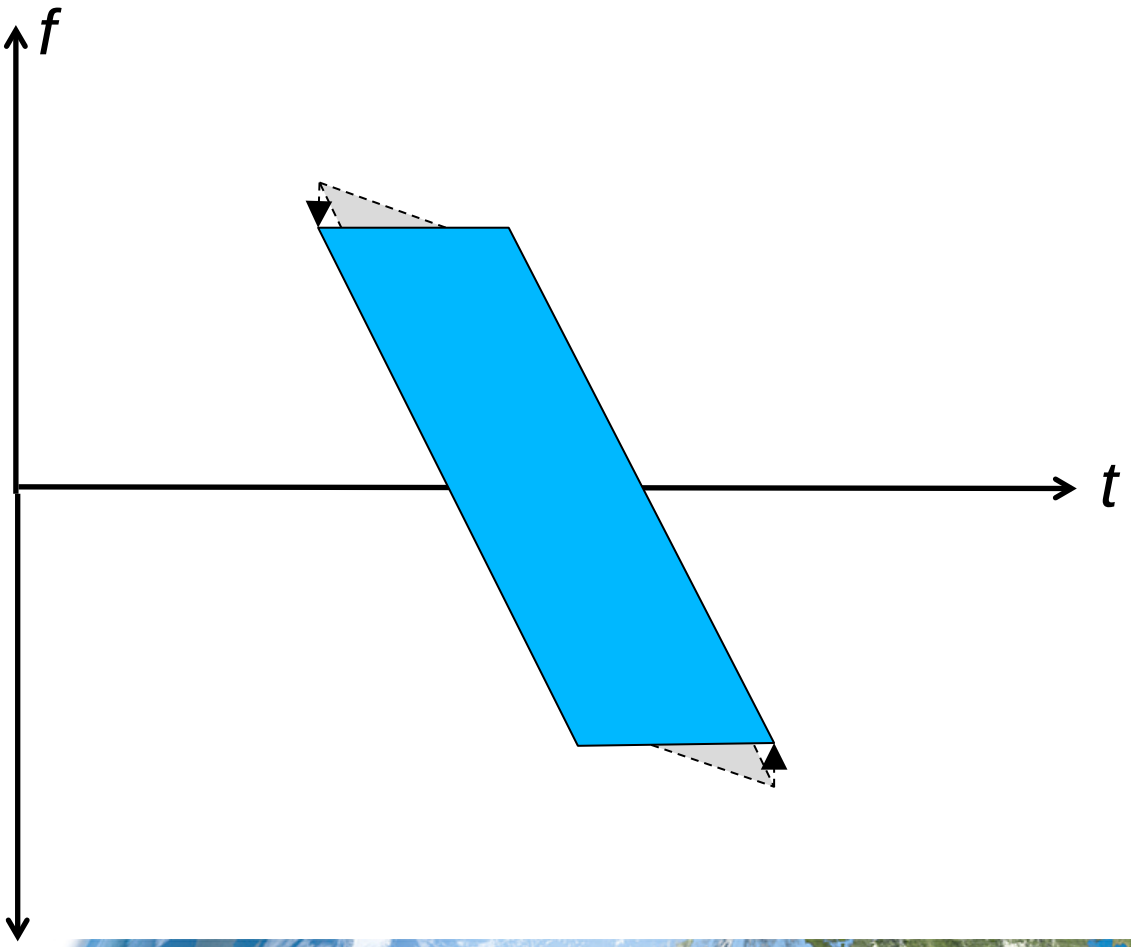
Tracking the Noise through the SAR Processor (Azimuth Compression)



Tracking the Noise through the SAR Processor (Azimuth Scaling)



Tracking the Noise through the SAR Processor (Deramping for Antenna Pattern Removal)



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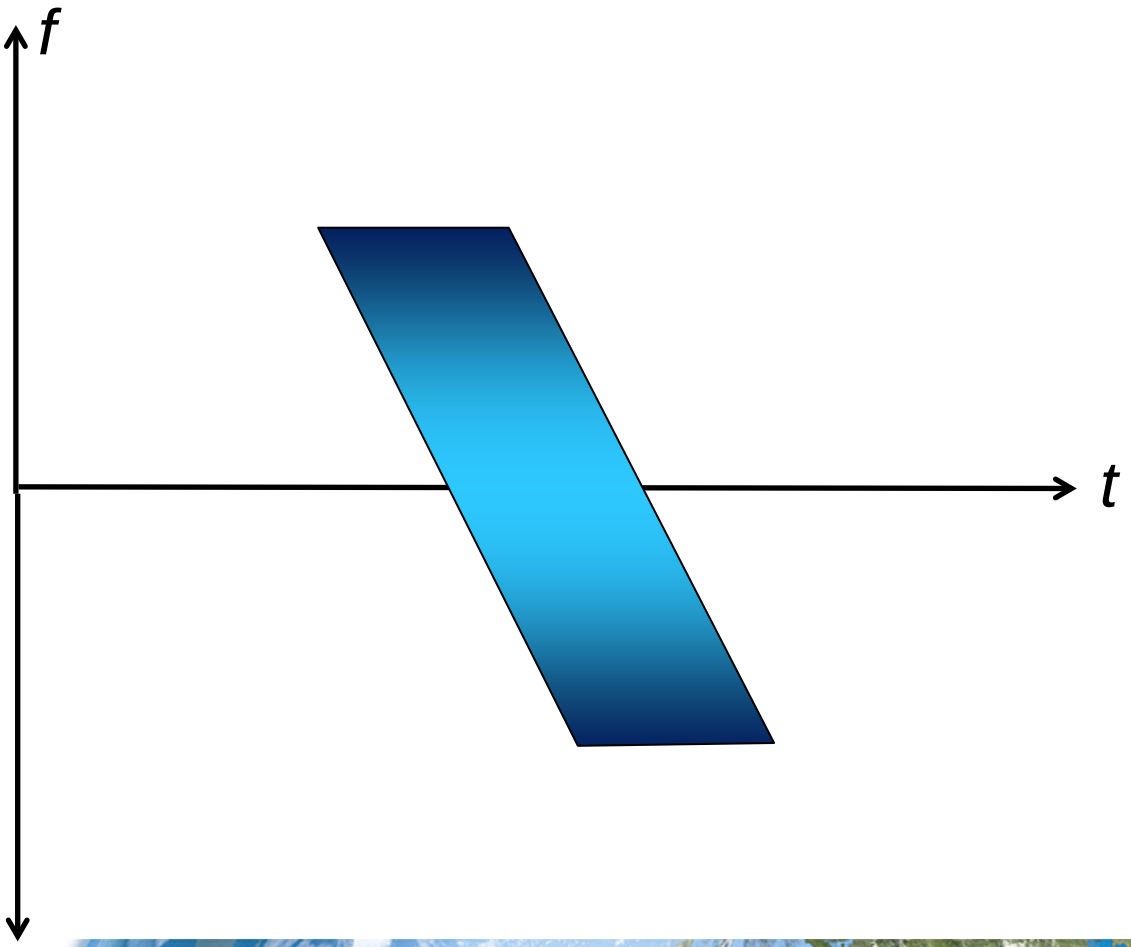
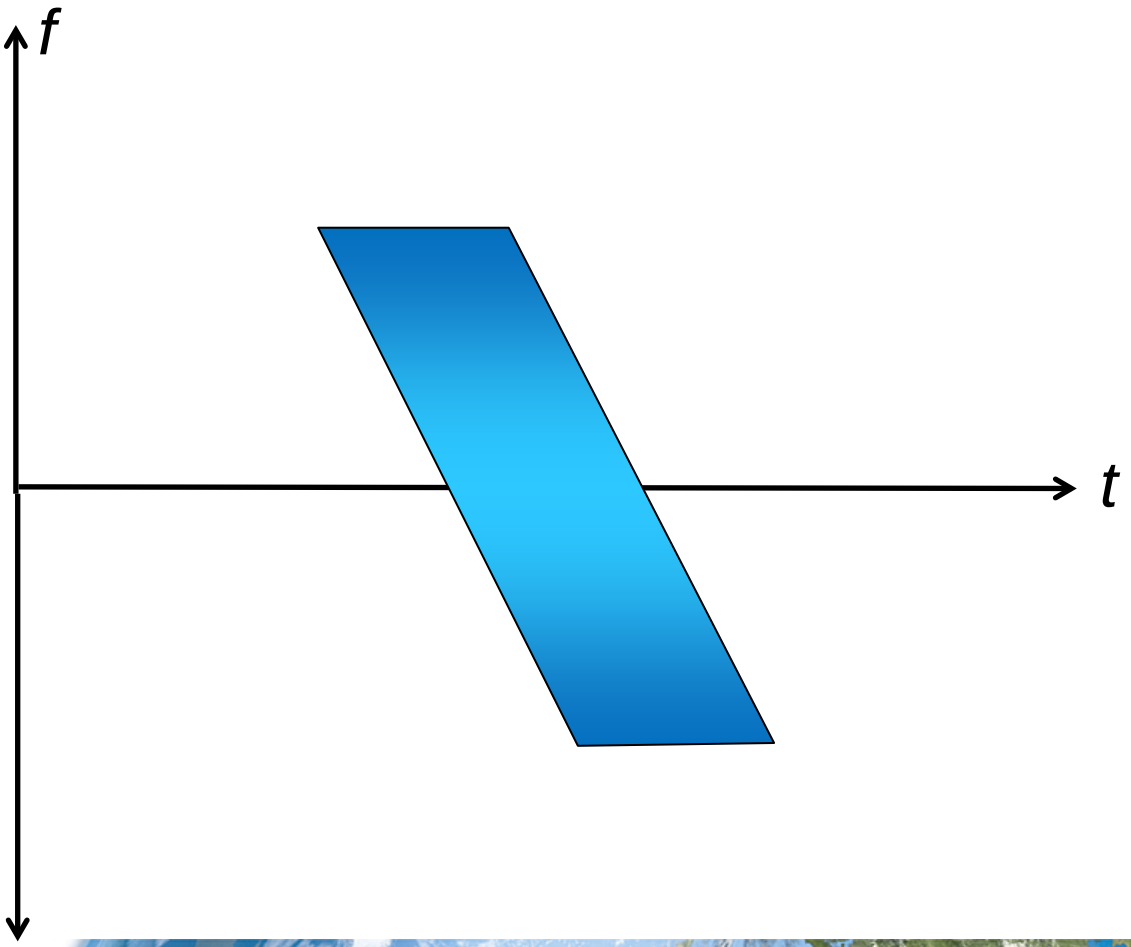
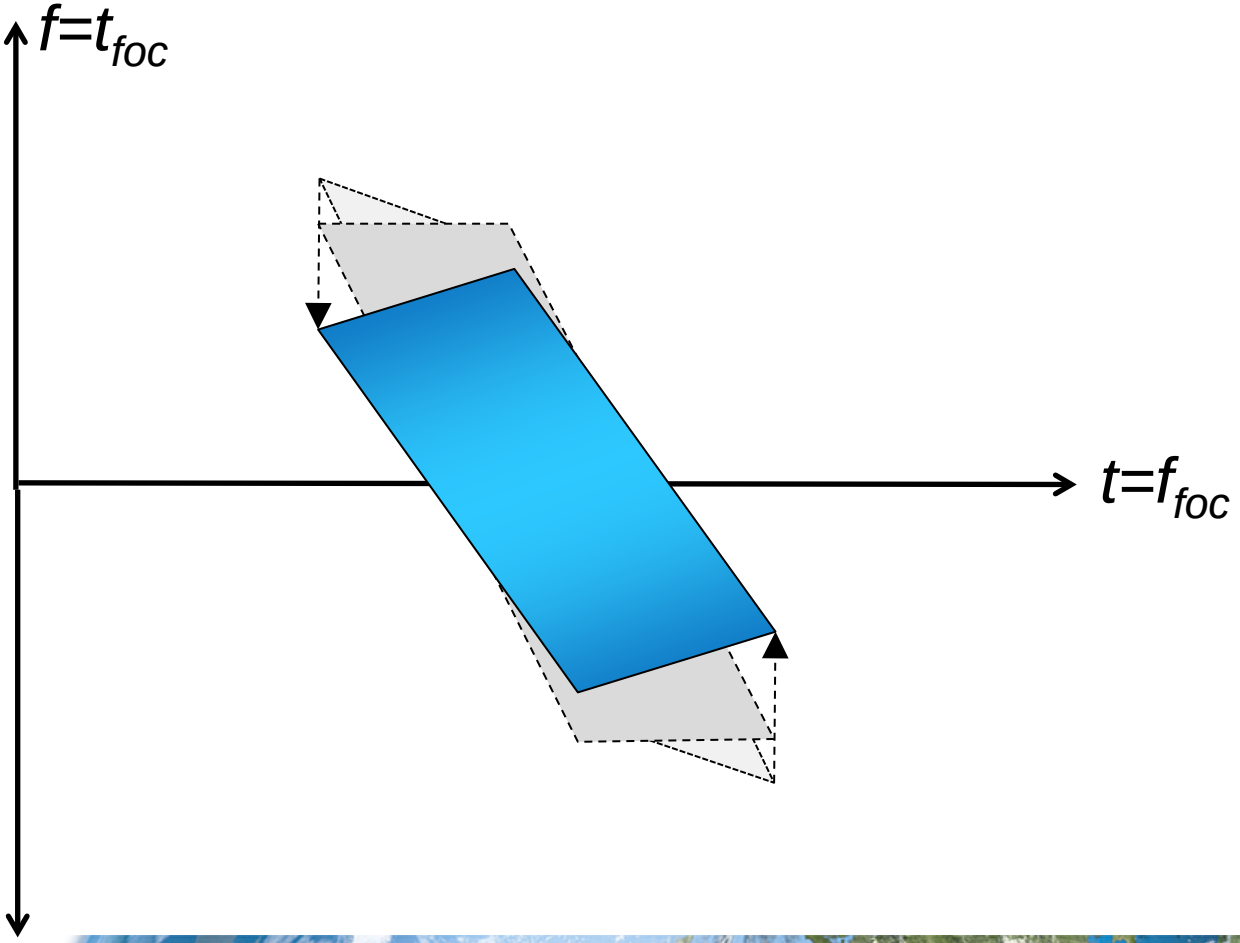


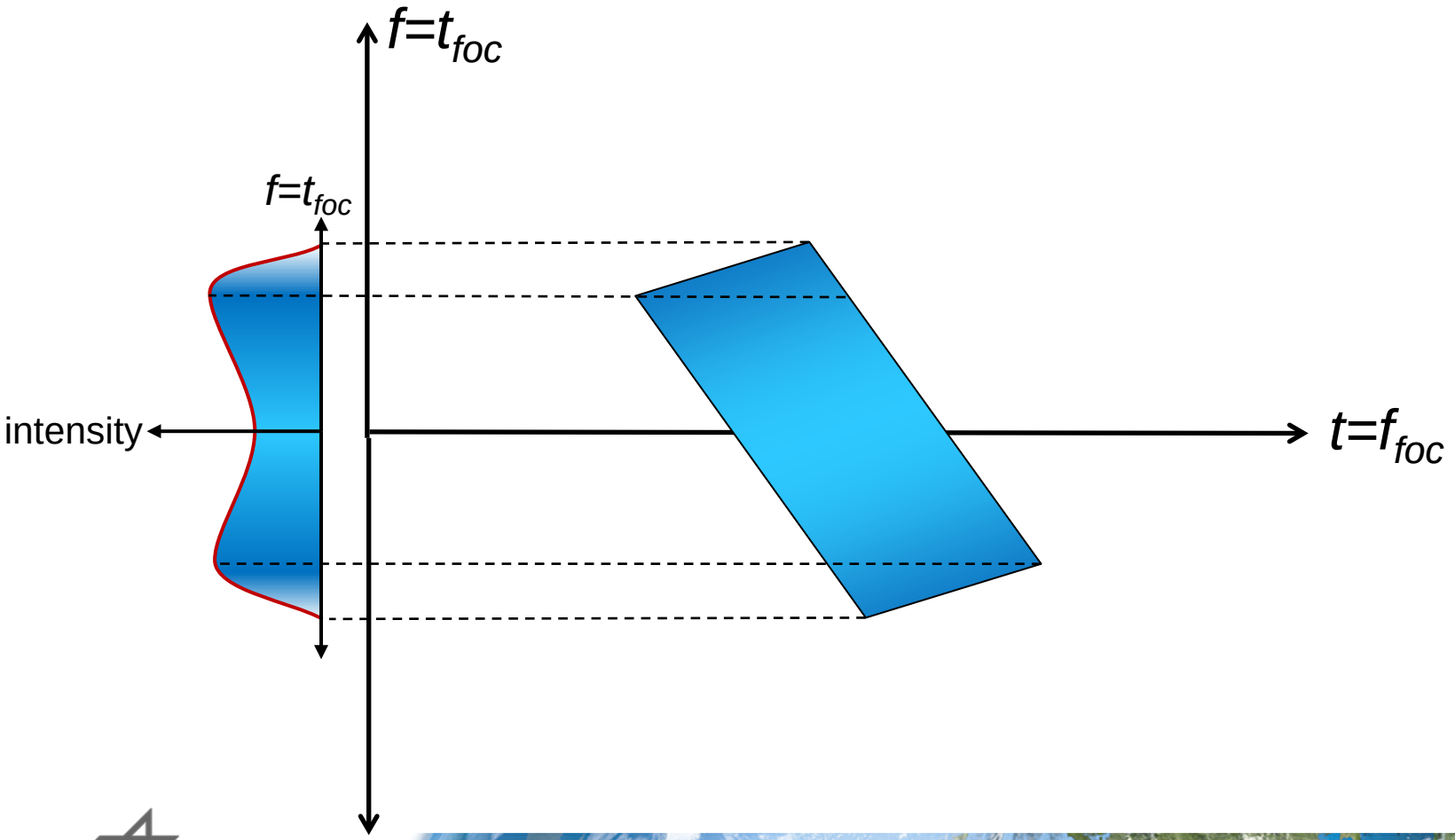
Tracking the Noise through the SAR Processor (Multiply by Hamming Window)



Tracking the Noise through the SAR Processor (Residual Deramping)



Tracking the Noise through the SAR Processor (Image in SPECAN Domain)



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  - Signal and noise gain might differ according to their different spectral properties
  - Keep in mind that in the processing chain, the input signal and noise is already changed by the predecessor steps
    - Don’t trust that white noise remains white after a filter step!
- **A correct processor normalization is indispensable:**
  - It is required from the first days of the mission!

Thank you for your attention!

Photo: © Robert Metzig, DLR-DFD 2014

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